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Flowshop Scheduling with Drum-Buffer-Rope and CDS Algorithm to Minimize Lateness and Work in Process at PT. AKS

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Abstract. In many years, the problem of lateness remains a problem for companies. This problem also occurs in textile company. At PT. AKS, one of the textile company, the lateness causes by bottleneck on one of their work station, which is Split Workstation, and the other caused by large unit load. The objective of this research is to minimize lateness by reducing the bottleneck and unit load. This research purposed a Drum-Buffer-Rope method and CDS algorithm to solve the problem. The constraint work station which is Split Workstation as the drum which is the control point of the whole system. The rope systematic which is backward scheduling applied at work stations before Split Workstation to minimize the queue time and to control the work in process. CDS Algorithm used in the interest of jobs sequencing to be processes after Split Workstation by using a forward scheduling. To solve the large unit load, we determine the unit load by trial and error. The result of this research manufacturing lead time decrease is by 61.88 percent from the current condition, queue time decrease is by 82.45 percent from current condition and the lateness decrease is by 35.71 percent from current condition.

Keywords: Flowshop scheduling, Drum-Buffer-Rope, CDS Algorithm

1. Introduction

PT. AKS as textile company produce a half-finished fabric i.e. polyester and cotton and produce a leather as material for clothes and shoes, their using a make to order system to fulfil the customer orders. The last four months, they faced a high demand of polyester, based on that condition, the company sustain a late delivery to customer. Based on survey and interviews, the root cause of late delivery are defect product and improper schedule which result in idle and bottleneck. Built upon the root cause, this research focus on improper schedule which inflict a high quantity of work in process.

This company produces various types of fabric, but the most common orders are polyester and cotton. Polyester and cotton production processes are carried out in different divisions, but at the end of the process, both types of fabric will be processed in the dyeing and finishing division. In the dyeing and finishing division there are eleven workstations, that is Partition Inspection, Mercerizing, Split, Dyeing, Calator, Centrifugal, Dryer, Callender, Setting, and Finishing.

The bottleneck occurs in Split Workstation, the input for four hours is 6000 kilograms or 237 rolls, meanwhile the output for four hours is 2400 kilograms or 96 rolls. From the current condition, there's no rule of sequencing the job, they process randomly, and it is resulting in late delivery to customers. According to the problem occur, this research proposes a scheduling and sequencing jobs to minimize a lateness and work in process.



There are several studies that discuss a job scheduling with Drum-Buffer-Rope Technique such as research conducted by [1] which applied Drum-Buffer-Rope for re-entrant flowshop and [2] which applied Drum-Buffer-Rope in aircraft industry.

Drum-Buffer-Rope method was chosen in this research because this method focuses on improvements in the workstation that has problems or the workstation that affect throughput. In this matter the workstation that is having problems is a workstation that has a bottleneck.

2. Methods

According to [3], Dr. Eliyahu Goldratt, the founder of Theory of Constraint, defined the constraint resource, the role of constraint in determining the output of organization, method to identify and exploit the constraint. Goldratt also gave the steps for ongoing improvement. The proposed steps for improvement are follows:

1. Identify the constraint system
2. Decide how to exploit these constraint
3. Sub-ordinate everything else to the above decision
4. Elevate the constraint system.
5. If in the above process generate other constraint, go back to the first step.

In this research, the research methodology was based on a practice-based research, the step of improvements adopts as describe on conceptual model as follow:

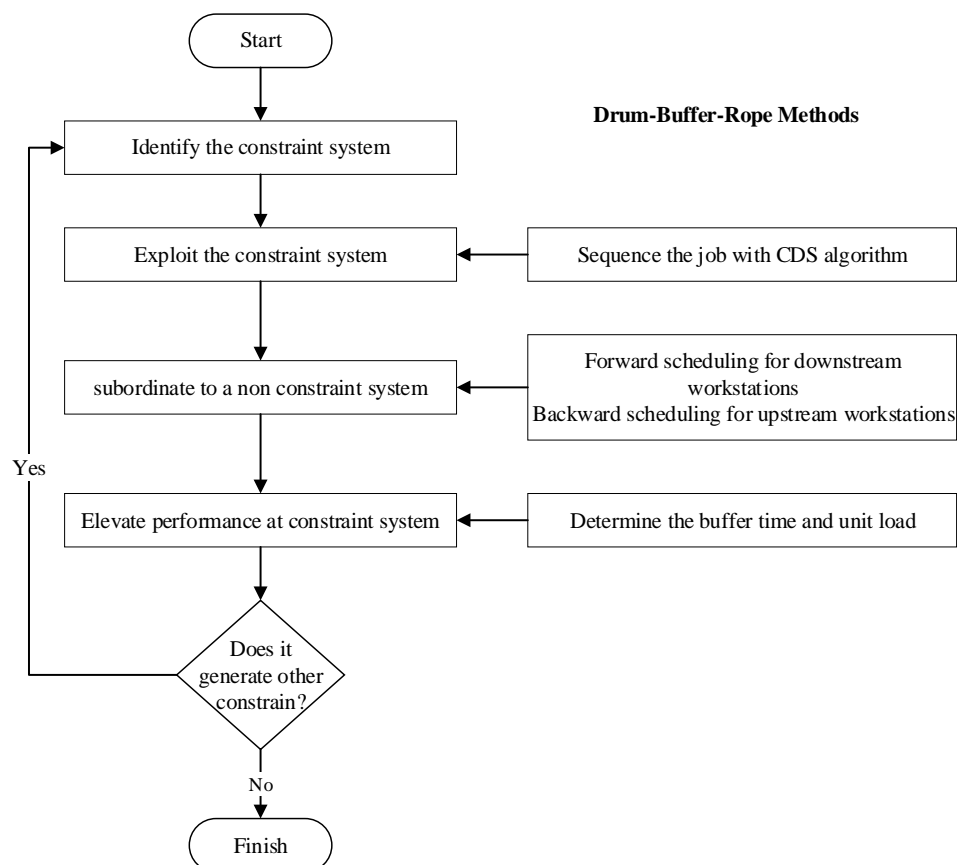


Figure 1. The Conceptual Model

The production control technique to implement the step of Theory of Constraint (TOC) which is exploiting, subordinating and elevating is Drum-Buffer-Rope [4]. Drum is bottleneck resource that drive the system, buffer placed before bottleneck operation, the purpose of the buffer is to preserve feeding

rate in the bottleneck resource, the buffers usually consist of three types: capacity buffer [5], time buffer [6] and stock buffer [7]. The rope is feedback loop which connecting the buffer to the raw material dispatching point.

The steps of Drum-Buffer-Rope technique as follows:

1. Scheduled the bottleneck resource.
2. Do the backward scheduling from bottleneck resource to first operation.
3. Do the forward scheduling from bottleneck resource to last operation.
4. Determine the buffer time in bottleneck resource.

From the step of exploit the constraint system, mostly, the sequencing in Drum-Buffer-Rope using SPT, EDD or random rule, but in this research, the jobs sequence is done using CDS Algorithm, this is because the processing time for all jobs in the constraint workstation is the same, so there is no difference with the actual conditions.

CDS algorithm is a scheduling method to get the optimal job sequence from n jobs to m machines. This scheduling is the development of Johnson's algorithm with heuristic approach and making several alternative job sequences to get the optimal scheduling. According to [8] the CDS algorithm applied the Johnson Rules in a heuristic manner and create several schedules from which the "best" schedule can be selected. The algorithm appropriate to a multistage use of Johnson's Rule applied to a pseudo-problem, reviled from the original, with processing times a_j and b_j . At stage 1, $a_j = p_{1j}$ and $b_j = p_{mj}$. In other term, the first and last processing times for each job involve the pseudo-problem. At stage 2, $a_j = p_{1j} + p_{2j}$ and $b_j = p_{m-1,j} + p_{mj}$. Here, the first two and last two processing times, accumulated for each job, involve the pseudo-problem. In general, at stage i ; $a_j = \sum_{k=1}^i P_{kj}$ and $b_j = \sum_{k=m-i+1}^m P_{kj}$. The procedure be composed of $(m - 1)$ stages, some of which may resulting the same sequence, after which the algorithm chooses the best makespan calculated.

The data used in this research were obtained from interviews and field observations. The data collected from Dyeing and Finishing Division is the cycle time data, the machine's productive time data which is the number of hours / shifts / working days, the machine capacity and routing data of the machine.

3. Result and Discussion

By following the Drum-Buffer-Rope steps, the result as follows:

1. Identify the constraint resource as the Drum.
In this case, the constrain resource is Split Workstation. The input in Split Workstation for four hours is 6000 kilograms or 237 rolls, meanwhile the output for four hours is 2400 kilograms or 96 rolls, which is the input bigger than output so that it can cause bottleneck and high value of work in process.
2. Determined the total time.
In this step calculate the total time for each job in each workstation, herewith the example of total time for several jobs.

Table 1. The example of total time for several jobs.

Job Code	Roll	Workstation	Processing Time	Setup Time	Move Time	Total Time
01	12	Inspection	11.06	1.17	1.56	12.23
	12	Split	29.30	0.41	3.27	29.71
	12	Jet Dyeing	24.21	1.93	6.54	26.14
	12	Centrifugal	16.09	4.85	5.60	20.95
	12	Setting	26.62	0.72	1.18	27.34
	12	Stenter	29.90	1.07	10.39	30.97
03	12	Inspection	11.02	1.17	1.56	12.19
	12	Split	29.30	0.41	3.27	29.71
	12	Jet Dyeing	27.21	1.93	6.54	29.14
	12	Centrifugal	16.09	4.85	5.60	20.95
	12	Setting	36.62	0.72	1.18	37.34
	12	Stenter	29.90	1.07	10.39	30.97

Table 1. The example of total time for several jobs (cont.).

07	12	Inspection	11.02	1.17	1.56	12.19
	12	Split	29.30	0.41	3.27	29.71
	12	Jet Dyeing	24.21	1.94	6.54	26.15
	12	Centrifugal	16.09	4.85	5.60	20.95
	12	Setting	26.62	0.72	1.18	27.34
	12	Stenter	27.40	1.07	10.39	28.47

3. Sequence the job with EDD, SPT and random rule in constraint resource.

The result of sequencing with EDD, SPT and random rule can be seen in Table 2. The sequence result with these three rules have the same results with current condition because all jobs has same processing time, therefore we use the CDS algorithm to sequences the jobs.

Table 2. The sequences of the job using EDD, SPT and random rule.

Job Code	Earliest Start	Latest Finish	Processing Time	Job Sequence
J01	0	1440	29.71	1
J02	0	1440	29.71	2
J03	0	1440	29.71	3
J04	0	1440	29.71	4
J05	0	1440	29.71	5
J06	0	1440	29.71	6
J07	0	1440	29.71	7
J08	0	1440	29.71	8
J09	0	1440	29.71	9
J10	0	1440	29.71	10
J11	0	1440	29.71	11
J12	0	1440	29.71	12
J13	0	1440	29.71	13
J14	0	1440	29.71	14
J15	0	1440	29.71	15
J16	0	1440	29.71	16

4. Sequence the job with CDS algorithm.

By using the CDS algorithm, there are five alternative job sequences. The result of CDS algorithm for all alternatives can be seen in Table 3. The best result of sequencing is alternative 4 and alternative 5, because both alternatives have the shortest makespan, which is equal to 2118.18. Both alternatives also have the same sequences.

Table 3. The alternatives of job sequence with CDS algorithm.

Alternative 1 (K = 1)	Makespan
J01-J02-J03-J04-J05-J06-J07-J08-J09-J10-J11-J12-J13-J14-J15-J16-J17-J18-J19-J20-J21-J22-J23-J24-J25-J26-J27-J28-J29-J30-J31-J32-J33-J34-J35-J36-J37-J38-J39-J40-J41-J42-J43-J44-J45-J46-J47-J48-J49-J50	2121.27
Alternative 2 (K = 2)	Makespan
J01-J02-J03-J04-J05-J06-J07-J08-J09-J10-J11-J12-J13-J14-J15-J16-J17-J18-J19-J20-J21-J22-J23-J24-J25-J26-J27-J28-J29-J30-J31-J32-J33-J34-J35-J36-J37-J38-J39-J40-J41-J42-J43-J44-J45-J46-J47-J48-J49-J50	2121.27
Alternative 3 (K = 3)	Makespan
J06-J15-J24-J33-J42-J05-J14-J23-J32-J41-J50-J03-J12-J21-J30-J39-J48-J04-J09-J13-J18-J22-J27-J31-J36-J40-J45-J49-J02-J11-J20-J29-J38-J47-J08-J17-J26-J35-J44-J01-J10-J19-J28-J37-J46-J07-J16-J25-J34-J43	2121.27

Table 3. The alternatives of job sequence with CDS algorithm (cont.).

Alternative 4 (K = 4)		
J01-J04-J07-J10-J13-J16-J19-J22-J25-J28-J31-J34-J37-J40-J43-J46-J49-	2118.18	
J02-J05-J08-J11-J14-J17-J20-J23-J26-J29-J32-J35-J38-J41-J44-J47-J50-		
J03-J06-J09-J12-J15-J18-J21-J24-J27-J30-J33-J36-J39-J42-J45-J48		
Alternative 5 (K = 5)		
J01-J04-J07-J10-J13-J16-J19-J22-J25-J28-J31-J34-J37-J40-J43-J46-J49-	2118.18	
J02-J05-J08-J11-J14-J17-J20-J23-J26-J29-J32-J35-J38-J41-J44-J47-J50-		
J03-J06-J09-J12-J15-J18-J21-J24-J27-J30-J33-J36-J39-J42-J45-J48		

5. Scheduling in Split Workstation.

The Split workstation is the point to be controlled for scheduled due to a bottleneck. Two kind scheduling approach used to solve problems, which is forward approach from Split workstation to the last work station and backward approach from Split workstation to first workstation.

According to research done by [2], following is the step of scheduling in Split workstation:

- Calculate the manufacturing lead time from Split workstation to last workstation
- Calculate the latest finish in Split workstation using backward approach.
- Calculate the earliest finish for all jobs in Split workstation.
- Calculate the earliest start in Split workstation.

The following are some of the results of scheduling based on constraint resource using alternatives 4.

Table 4. The example of result of scheduling

Job Code	Operation	Workstation	Start	Finish
J01	1	Inspection 1	0.00	24.36
	2	Split	25.92	55.63
	3	Jet Dyeing 1	58.90	320.30
	4	Centrifugal	326.85	347.80
	5	Setting 1	353.40	408.06
	6	Stenter 1	409.24	471.17
J04	1	Inspection 2	0.00	54.07
	2	Split	55.63	85.34
	3	Jet Dyeing 2	88.61	350.01
	4	Centrifugal	356.56	377.50
	5	Setting 2	383.10	437.77
	6	Stenter 2	438.95	515.88
J07	1	Inspection 1	24.36	83.78
	2	Split	85.34	115.05
	3	Jet Dyeing 3	118.32	379.72
	4	Centrifugal	386.27	407.21
	5	Setting 1	412.81	467.48
	6	Stenter 1	471.17	528.09
J10	1	Inspection 2	54.07	113.49
	2	Split	115.05	144.76
	3	Jet Dyeing 4	148.03	409.43
	4	Centrifugal	415.97	436.92
	5	Setting 2	442.52	497.19
	6	Stenter 2	515.88	577.80

Table 4. The example of result of scheduling (cont.).

Job Code	Operation	Workstation	Start	Finish
J13	1	Inspection 1	83.78	143.20
	2	Split	144.76	174.47
	3	Jet Dyeing 5	177.74	439.14
	4	Centrifugal	445.68	466.63
	5	Setting 1	472.23	526.90
	6	Stenter 1	528.09	605.02

6. Calculate the buffer time in Drum.

Recommended size of buffer time is $\leq 10\%$ from total lead time in actual condition, however the optimum size is appropriate with the requirement of shop floor [3]. In this research, the buffer time be appointed as 5% from total lead time.

7. Calculate the unit load with trial and error.

Unit load aims to get the optimal amount to be moved and processed from one work station to another work station. In actual conditions the company uses a unit load of 12 rolls or fit to maximum capacity of MHE. The exploitation of the constraints is done by delivering the fabric and processing it in a Split Workstation in the amount of 3, 4, or 6 based on lot packaging of fabric and minimal fabric capacity in jet dyeing machines. Following is the result of unit load:

Table 5. The result of unit load determination.

Unit Load	Makespan
12 rolls (actual condition)	2121.27
6 rolls	1920.11
4 rolls	1903.47
3 rolls	1901.47

Based on calculation of unit load, we have the best unit load with the shortest makespan which three rolls per delivery.

Overall, the following is the comparison between the actual condition and proposed condition:

Table 6. The comparison between actual and proposed condition.

Performance	Actual Condition	Proposed Condition	Decrease
Manufacturing lead time average	1024.04 minutes	390.31 minutes	61.88%
Queue time average	435.55minutes	76.41 minutes	82.45%
Lateness	252 rolls	162 rolls	35.71%
Makespan	2121.27 minutes	1901.47 minutes	10.36%

4. Conclusion

In the actual condition, a set of jobs that must be processed do not have a clear job sequence, so that the sequence of the job is done randomly. This has resulted in delays in producing fabric due to a bottleneck, delays in completing orders at one of the workstation impacting on the completion of orders at other work stations.

The use of drum buffer rope method in the proposed condition with the initial step of making the workstation constrained as a drum that functions as a control point, can improve the overall performance of the system. In the proposed conditions, improvements are made by exploiting the constraint system, by scheduling jobs at the workstation constraints first, then doing rope or backward scheduling to determine the right time so that the job arrives at the Split Workstation according to the machine's ability. To anticipate delays that occur at workstations before the Split Workstation, buffer time is applied so that the job arrives faster as if there is an optimum buffer stock in the Split Workstation. Finally, forward

scheduling from Split Workstation to the last workstation and continue to improve system performance by calculating the unit load so that the best quantity can be obtained that minimizes system constraints and improves the whole system. The result of this research is the manufacturing lead time decrease is by 61.88 percent from the current condition, queue time decrease is by 82.45 percent from current condition and the lateness decrease is by 35.71 percent from current condition.

5. References

- [1] Chang Y C and Huang W T 2011 Using simplified drum-buffer-rope for re-entrant flowshop scheduling in a random environment *African Journal of Business Management* **5**(26) pp 10796-10810
- [2] Rieswien R, Suryadhini P P and Juliani W 2014 Perancangan Sistem Scheduling Job Menggunakan Drum Buffer Rope untuk Meminimasi Keterlambatan Order dan Manufacturing Lead Time pada Bagian Machining MPM di PT. Dirgantara Indonesia *Jurnal Rekayasa Sistem dan Industri* **1** pp 14–21
- [3] Bhardwarj A, Gupta A and Kanda A 2010 Drum-Buffer-Rope: The technique to plan and control the production using theory of constraints. *Int. J. of Industrial and Manufacturing Engineering* **4**(9) pp 784-787
- [4] Sipper D and Bulfin R L Jr 1997 *Production Planning, Control and Integration* (New York: The McGraw-Hill) pp 577
- [5] Schmitt T G 1984 Resolving uncertainty in production systems *Journal of Operations Management* **4**(4) pp 331–345
- [6] Chang C A, Brown L G and Johnson L R 1983 Analysis of buffering techniques in MRP systems with a matrix loading model. *IIE Trans* **15** pp 305–312
- [7] New C and Mapes J 1984 MRP with high uncertain yield losses *Journal of Operations Management* **4** pp 315–330
- [8] Baker K R and Trietsch D 2009 *Principles of Sequencing and Scheduling* (New Jersey: John Wiley and Son)